NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

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EFFECTS OF ANTISPIN FILLETS AND DORSAL FINS ON THE SPIN AND RECOVERY CHARACTERISTICS OF AIRPLANES AS DETERMINED FROM FREE-SPINNING-TUNNEL TESTS

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SUMMARY

The effects of antispin fillets and dorsal fins on the spin and recovery characteristics of airplanes have been determined from an analysis of the results of spinning investigations of a large number of models tested in the Langley 15-foot and 20-foot free-spinning tunnels.

The analysis indicated that when antispin fillets were installed on an airplane, the fuselage area below the fillets became more effective in damping the spinning rotation (higher tail-damping ratio). Whether or not fillets satisfactorily improved recovery characteristics of a given design depended, with few exceptions, upon the tail-damping power factor of the design with fillets installed and upon the mass distribution and relative density of the airplane. The results indicated that dorsal fins generally had little effect on spin and recovery characteristics.

INTRODUCTION

During approximately 13 years of operation of the Langley 15-foot and 20-foot free-spinning tunnels, model tests have been made for approximately 200 different military airplane designs to determine their spin and recovery characteristics. During these tests the various flying conditions of the airplane were usually investigated, and when the results indicated that the spin and recovery characteristics would be unsatisfactory, dimensional modifications were made to the model and recommended for the airplane such that the final design would possess satisfactory spin and recovery characteristics. The recommended modifications, in most cases, consisted of increasing the tail length, raising the horizontal tail, or adding a ventral fin. For some cases, however, these modifications were not considered feasible and other modifications were studied. One such modification that was found effective in improving the spin-recovery characteristics was the installation along the fuselage of narrow extensions of the horizontal stabilizer designated as antispin fillets. An analysis of the results of tests of such fillets has been made in order to determine the important factors governing their action.

On the basis of very meager data, it was indicated in reference 1 that the action of antispin fillets was dependent upon making the fuselage area below them effective in damping spin rotation (increasing tail-damping ratio) and it was assumed that the unshielded rudder area was unchanged. Data from 21 different models have been used in the present paper to determine the action of fillets as regards damping of the spin rotation. Consideration was also given to the possibility that the fillet may in some cases shield parts of the rudder and, consequently, reduce the rudder effectiveness and that the wing and fuselage may shield the fillet and, thereby, reduce fillet effectiveness.

The independent effect of dorsal fins on the spin and recovery characteristics has also been obtained from available data for 30 models. Dorsal fins have usually been installed on spin-tunnel models when, in the course of development of the airplane, their installation was deemed necessary from considerations of normal-flight stability characteristics.

SYMBOLS

ρ	air density at a given altitude, slug per cubic foot
S	wing area, square feet
b	wing span, feet
W	weight, pounds
g	acceleration of gravity (32.17 ft/sec^2)
m	mass, slugs (W/g)
μ	airplane relative-density coefficient
I_X, I_Y	moments of inertia about X and Y airplane body axes, respectively, slug-feet^2
$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
TDR	tail-damping ratio (reference 1)
URVC	unshielded rudder volume coefficient (reference 1)

TDPF tail-damping power factor (product of tail-damping ratio and unshielded rudder volume coefficient, reference 1)

α angle of attack, degrees

Ω angular velocity about spin axis, revolutions per second

V rate of vertical descent, feet per second

$\Omega b/2V$ spin coefficient

ϕ angle between span axis and horizontal, degrees

U inner wing up

D inner wing down

q dynamic pressure, pounds per square foot $\left(\frac{1}{2}\rho V^2\right)$

C_l rolling-moment coefficient $\left(\frac{\text{Rolling moment}}{qSb}\right)$

C_m pitching-moment coefficient $\left(\frac{\text{Pitching moment}}{qSb}\right)$

C_n yawing-moment coefficient $\left(\frac{\text{Yawing moment}}{qSb}\right)$

Moments measured about body axes

METHODS

For the analysis of the effectiveness of antispin fillets, the models were separated into groups based on the effect on the recovery characteristics. The tail-damping power factors were computed for each model with and without fillets installed in accordance with the method indicated in reference 1, modified as a result of the present analysis, and plotted as a function of the inertia yawing-moment parameter. In order to separate the models in these plots according to fillet effectiveness, various symbols were employed to indicate the degree of fillet effectiveness on the model recovery characteristics. Plots were made for three relative-density ranges.

Because the data indicated that dorsal fins had little effect, no detailed analysis was made to determine their action during the spin or recovery.

Tests

The steady-spin and recovery data used for the analysis in this paper were obtained from investigations of specific airplane models in the Langley 15-foot and 20-foot free-spinning tunnels.

The methods used for making spin-tunnel tests are described in reference 2, although in recent years the model launching technique has been changed from launching from a spindle to launching by hand. Briefly, a model ballasted by means of lead weights to obtain dynamic similarity to a full-scale airplane at some altitude is launched by hand with rotation into a vertically rising air stream with the controls set in a desired position. After a number of turns, the model assumes its spin attitude and is maintained at a specified level in the tunnel by adjusting the airspeed so that the model drag equals its weight. After a number of turns in the established spin have been photographed and timed, a recovery attempt is made by moving one or more controls by means of a remote-control mechanism; if recovery is effected, the model dives or glides into a safety net. The data obtained from the tests are converted to corresponding full-scale values by methods described in reference 2. Maximum and intermediate control settings are investigated. Airplane recovery characteristics are considered satisfactory if the model recovers in 2 turns or less from the steady spin when in the normal spinning control configuration (ailerons neutral, elevator up, and rudder full with the spin) and if the model recovers in $2\frac{1}{4}$ turns or less even with small deviations from this control configuration. A control configuration designated as the criterion spin indicates the effect of small deviations from the normal spinning control configuration. For the criterion spin, ailerons are deflected 1/3 of their full deflection in the direction leading to slow recoveries, the elevator is set to only 2/3 of its full-up deflection, and recovery is attempted by reversal of the rudder to only 2/3 full against the spin. The symbol ∞ indicates that the model required 10 turns or more for recovery or did not recover at all.

Factors Considered

In order to determine the effectiveness of antispin fillets on a given design, the spin-recovery data were compared for the model with and without the fillets installed. This comparison was made for recovery by full rudder reversal from the normal spinning control configuration and for recovery from the criterion spin.

The models were separated into groups on the following basis:

Turns originally required for recovery	Turns required for recovery with fillets installed	[1]Effect of fillet on recovery
5 or more	$3\frac{1}{4}$ or more	None
5 or more	3	Slightly favorable
3 or more	$2\frac{1}{4}$	Slightly favorable
$2\frac{3}{4}$ or more	2 or less	Satisfactory
$2\frac{3}{4}$ or $2\frac{1}{2}$	$1\frac{3}{4}$ or less	Satisfactory
$2\frac{1}{4}$	$1\frac{1}{2}$ or less	Satisfactory
2	3/4 or less	Satisfactory

[1]Any recoveries within 1/2 turn of one another were considered as indicating no effect inasmuch as this is within the range of experimental error.

After the models were separated into groups indicated by the effect on their respective recovery characteristics of antispin fillets, the tail-damping power factor was computed, as previously indicated, for each model with the fillets installed by use of the method described in reference 1 whereby the fuselage area under the fillet is considered effective in damping rotation.

In an attempt to obtain a more complete picture of the action of antispin fillets in the spin, however, it was considered that:

(a) For steep spins, the wake of the wing may shield part or all of the fillet and consequently reduce or eliminate the area of the fuselage under the fillet that is effective in damping the spin rotation.

(b) For certain fuselage cross sections, the wake of the fuselage may shield the fillet and consequently reduce the area of the fuselage under the fillet that is considered effective in damping the spin rotation.

(c) For certain positions of the fillet in relation to the rudder, the fillet may shield part of the rudder that was previously unshielded and thus reduce the unshielded rudder volume coefficient if angles of attack and the sideslip angles at the tail of the spinning model are taken into account.

(d) When the fillet was faired into the fuselage in such a manner that the forward end of the fillet was very narrow, this end would probably be ineffective in increasing the damping ability of the fuselage area under the fillet.

RESULTS AND DISCUSSION

Table I lists some of the mass and dimensional parameters for the models considered in the investigation as well as their recovery characteristics before and after fillet installation. For some models, data are presented for more than one antispin fillet tested and, in some cases, one antispin fillet was tested on a model for several loading conditions. Sketches of antispin fillets that had a satisfactory effect on spin-recovery characteristics are presented in figure 1.

In investigating the possible shielding of the fillet by the wing, a wake line was drawn from the trailing edge of the wing at the wing-fuselage juncture and made an angle with the wing chord which was 15° less than the angle of attack. The value of the tail-damping power factor was computed (see reference 1), based on the area below the fillet and outside the wake line. For several of the models for which fillets had a satisfactory effect on spin recoveries, consideration of possible shielding of the fillets by the wing reduced the values of the tail-damping power factor to such an extent that the value was below the minimum value of TDPF recommended to insure satisfactory recovery as presented in reference 1. It thus appeared that shielding of the fillets by the wing was unlikely and for further calculations of TDPF, this effect was disregarded.

In considering possible shielding of the fillets by the fuselage, when located above the station of maximum thickness, and also possible shielding of the rudder by the fillets, use was made of the angle of attack of the spin and of an average value of the sideslip angle at the tail of 12°. Calculations were made of the tail-damping power factor based on the possible shielding of the fillets by the fuselage (causing a reduction of the tail-damping ratio) and of the possible shielding of the rudder by the fillets (causing a reduction of the unshielded rudder volume coefficient). Consideration of these factors reduced the value of TDPF to such an extent for some models, for which fillets led to satisfactory recovery characteristics, that the value was below the minimum value of TDPF recommended to insure satisfactory spin recovery presented in reference 1. Fuselage shielding of the fillets and fillet shielding of the rudder were unlikely and, therefore, these effects were disregarded for further calculations of TDPF.

It was recognized that if the fillet was faired into the fuselage in such a manner that the forward end of the fillet was very narrow, this faired part would probably be ineffective in increasing the damping ability of the fuselage area under the fillet. Accordingly, it was believed that some minimum angle in the plane of the fillet, at which the fillet joined the fuselage at the forward end, should be used to determine the effective length of the fillet. Inasmuch as the minimum value of this angle was 12° for fillets which, in the present study, indicated satisfactory effects on spin recovery, this angle was arbitrarily selected. For a fillet that made an angle of less than 12° with the fuselage at its forward end, the area of the fuselage under the fillet considered as contributing to tail damping was only that area under the largest possible fillet within the contour of the original fillet which faired into the fuselage at an angle of 12°. (See fig. 2.) Values of TDPF were recalculated for all models having fillets joining the fuselage at angles less than 12° and a better separation between models for which fillets had a satisfactory effect and models for which fillets either exhibited no effect or a small effect (slightly favorable) was evident. This factor should, therefore, be considered in calculation of TDPF when fillets are installed.

Figures 3 to 5 indicate the effects of antispin fillets on the recovery characteristics of the models for three relative-density ranges and for various values of tail-damping power factor and inertia yawing-moment parameter. The regions determined in reference 1 for satisfactory and unsatisfactory recovery characteristics are indicated in the figures. The plotted values of tail-damping power factor were computed by considering all the fuselage area under the fillet as contributing to tail damping with the exception of the area under that part of the fillet making an angle of less than 12° with the fuselage; for these fillets, the method previously described and recommended for future use was employed. It appears from figures 3 to 5 that whether or not antispin fillets will satisfactorily improve recovery characteristics of a given design will generally depend upon the tail-damping power factor of the design with fillets installed and upon the mass distribution and relative density of the airplane.

The results presented in figure 6 indicate that the addition of antispin fillets, for the models considered in this investigation, usually caused the angle of attack of the spinning model to steepen so that better recoveries were generally made.

A few tests were made for a low-wing fighter-type airplane model (model 5A) attached to a rotary balance mounted in the Langley 20-foot free-spinning tunnel. The rolling-, pitching-, and yawing-moment coefficients presented in figure 7 were measured with and without the fillets which had previously indicated a satisfactory effect upon recovery characteristics during free-spinning tests. The tests were made for an angle of attack range up to 90°, $\Omega b/2V$ was kept constant at a typical value of 0.30, and the wing tilt angle and the spin radius were maintained at zero. The results indicated that antispin fillets generally had little effect on rolling and pitching moments, although at very high angles of attack, fillets did indicate a small nose-down pitching moment. Installation of fillets generally created, at moderate and high angles of attack, an antispin yawing moment which for the particular model tested was enough to eliminate the flatter of the two types of spin originally obtained without the fillets and thus insure rapid recoveries.

An investigation of spin results obtained with the installation of dorsal fins indicated that generally dorsal fins had little effect on the spin and recovery characteristics of the models. Inasmuch as dorsal fins had such a small effect on the spin recovery, data are presented only for two typical models (one of which spins steeply and the other of which spins flat) for which dorsal fins were installed. These data are presented in table II as are also sketches of the dorsal fins.

CONCLUSIONS

Based on an analysis of the results of free-spinning-tunnel investigations on numerous models for which antispin fillets and dorsal fins were tested, the following conclusions were made:

1. The effectiveness of antispin fillets for spin recovery appeared to depend primarily upon the fact that the fuselage area below the fillet became effective in damping the spin rotation. The portion of the fuselage area effective in damping the rotation was all area below the fillet, except that forward of the station at which the fillet joined the fuselage at an angle less than 12°.

2. Whether or not antispin fillets satisfactorily improved recovery characteristics of a given design generally depended upon the tail-damping power factor of the design with fillets installed and upon the mass distribution and relative density of the airplane.

3. Dorsal fins generally had little effect on spin and recovery characteristics.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., October 11, 1948

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2. Zimmerman, C. H.: Preliminary Tests in the N.A.C.A. Free-Spinning Wind Tunnel. NACA Rep. No. 557, 1936.

TABLE I.- MASS AND DIMENSIONAL PARAMETERS FOR MODELS USED IN FILLET INVESTIGATION AND RESPECTIVE RECOVERY CHARACTERISTICS BEFORE AND AFTER FILLET INSTALLATION

Model	$\frac{I_X - I_Y}{mb^2}$	URVC	TDR (without fillet)	TDPF (without fillet)	TDR (fillet installed)	TDPF (fillet installed)	μ (at test altitude)	Turns for recovery required for normal control configuration		Turns for recovery required for criterion spin	
								Without fillet	With fillet	Without fillet	With fillet
1	-148×10^{-4}	0.01056	0.0252	267×10^{-6}	0.0363	383×10^{-6}	13.12	-------	------	$1\frac{1}{2}$, >2	$1\frac{1}{4}$, $1\frac{1}{2}$
2A	-188	.0390	.0209	814	.0454	1777	17.7	-------	------	$4\frac{1}{4}$	2, $2\frac{1}{4}$
2B	-244	.0390	.0209	814	.0454	1777	18.2	-------	------	∞	$1\frac{1}{2}$, 2, $2\frac{1}{2}$
2C	-244	.0390	.0209	814	.0409	1595	18.2	-------	------	∞	2, $2\frac{3}{4}$, $3\frac{1}{4}$
3A	-142	.0035	.0113	40	.0226	79	25.5	∞	$\frac{3}{4}$, 1	-------	------
3B	-142	.0035	.0113	40	.0301	106	25.5	∞	$\frac{1}{2}$, $\frac{3}{4}$	-------	------
[a]3C	-142	.0110	.0212	234	.088	968	25.5	$\frac{1}{2}$, 1	1, $1\frac{1}{2}$	-------	------
4A	-125	.00511	.0285	146	.0374	191	17.65	[b]4, [b]$4\frac{1}{2}$ [b,c]$>\frac{3}{4}$, [b,c]2	[c,d]$1\frac{1}{4}$, [c,d]$1\frac{1}{2}$	-------	------
4B	-125	.00511	.0285	146	.0417	213	17.65	[b]4, [b]$4\frac{1}{2}$ [b,c]$>\frac{3}{4}$, [b,c]2	[c,d]$\frac{3}{4}$, [c,d]1	-------	------
4C	-125	.00511	.0285	146	.0437	223	17.65	[b]4, [b]$4\frac{1}{2}$ [b,c]$>\frac{3}{4}$, [b,c]2	No spin	∞	1, $1\frac{1}{4}$
4D	-90	.00511	.0285	146	.0437	223	17.65	[b]5 [b,c]$\frac{3}{4}$, [b,c]$\frac{3}{4}$	[c,d]$\frac{3}{4}$, [c,d]1	-------	------
4E	-125	.00511	.0285	146	.0454	232	17.65	[e]∞	[e]$\frac{3}{4}$	-------	------
4F	-125	.00511	.0285	146	.0492	251	17.65	[e]∞	[e]$\frac{3}{4}$	-------	------

[a]Without fillet, recoveries from all control settings except normal control configuration and aileron-with, elevator-up setting were unsatisfactory. Fillet installation caused recoveries from these spins to be very satisfactory.
[b]Two types of spin.
[c]Recovery attempted before final steep attitude was attained.
[d]Flatter of two types of spin obtained without fillets was eliminated with fillets installed.
[e]Elevator neutral.

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TABLE I.- MASS AND DIMENSIONAL PARAMETERS FOR MODELS USED IN FILLET INVESTIGATION AND RESPECTIVE RECOVERY CHARACTERISTICS BEFORE AND AFTER FILLET INSTALLATION - Continued

Model	$\frac{I_X - I_Y}{mb^2}$	URVU	TDR (without fillet)	TDPF (without fillet)	TDR (fillet installed)	TDPF (fillet installed)	μ (at test altitude)	Turns for recovery required for normal control configuration		Turns for recovery required for criterion spin	
								Without fillet	With fillet	Without fillet	With fillet
5A	-137×10^{-4}	0.00948	0.0292	277×10^{-6}	0.0494	468×10^{-6}	17.65	[b]>4, [b,c]$\frac{3}{4}$	[d]Steep spin	-------	------
5B	-137	.00948	.0292	277	.0528	500	17.65	[b]>4, [b,c]$\frac{3}{4}$	[d]$\frac{1}{2}$	-------	------
5C	-137	.00948	.0292	277	.0395	375	17.65	[b]>4, [b,c]$\frac{3}{4}$	>6	-------	------
6A	-117	.0109	.01702	186	.0209	229	10.60	$\frac{1}{2}$	1	[b]4, [b]$4\frac{1}{2}$, [b]$\frac{3}{4}$	[d]$1\frac{1}{4}$, [d]$1\frac{1}{2}$
6B	-117	.0109	.01702	186	.0261	284	10.60	$\frac{1}{2}$	1	[b]4, [b]$4\frac{1}{2}$, [b]$\frac{3}{4}$	[d]$1\frac{1}{4}$, [d]$1\frac{1}{2}$
7A	-72	.0163	.0220	359	.0351	572	15.77	[b,c]1, [b,c]$1\frac{1}{4}$, [b,c]$1\frac{3}{4}$, [b,c]2	[b]$1\frac{1}{2}$, [b]2, [b,c]$\frac{1}{2}$, [b,c]$\frac{3}{4}$	4, $4\frac{1}{2}$	[b]$1\frac{3}{4}$, [b]2, [b,c]$\frac{1}{2}$, [b,c]1
7B	-72	.0163	.0220	359	.0465	757	15.77	[b,c]1, [b,c]$1\frac{1}{4}$, [b,c]$1\frac{3}{4}$, [b,c]2	[b]$\frac{3}{4}$, [b]1, [b]$2\frac{3}{4}$	4, $4\frac{1}{2}$	$1\frac{1}{2}$
7C	-72	.0163	.0220	359	.0431	704	15.77	[b,c]1, [b,c]$1\frac{1}{4}$, [b,c]$1\frac{3}{4}$, [b,c]2	>$1\frac{1}{2}$	4, $4\frac{1}{2}$	[b]$3\frac{1}{4}$, [b]$3\frac{1}{2}$ Steep spin

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[b]Two types of spin.
[c]Recovery attempted before final steep attitude was attained.
[d]Flatter of two types of spin obtained without fillets was eliminated with fillets installed.

TABLE I.- MASS AND DIMENSIONAL PARAMETERS FOR MODELS USED IN FILLET INVESTIGATION AND RESPECTIVE RECOVERY CHARACTERISTICS BEFORE AND AFTER FILLET INSTALLATION - Continued

Model	$\frac{I_X - I_Y}{mb^2}$	URVC	TDR (without fillet)	TDPF (without fillet)	TDR (fillet installed)	TDPF (fillet installed)	μ (at test altitude)	Turns for recovery required for normal control configuration		Turns for recovery required for criterion spin	
								Without fillet	With fillet	Without fillet	With fillet
8A	-28×10^{-4}	0.01139	0.0223	254×10^{-6}	0.0359	409×10^{-6}	16.63	Right spin, $6\frac{1}{2}$ Left spin, very steep	Right spin, $1\frac{1}{4}$ Left spin, very steep	-------	------
8B	-28	.01139	.0223	254	.0407	463	16.63	Right spin, ∞	Right spin, $2\frac{1}{2}$, $2\frac{3}{4}$	-------	-------
9	-117	.0109	.01702	186	.0261	284	17.50	$1\frac{1}{4}$, $1\frac{3}{4}$	$1\frac{1}{2}$	[b]9 [b]$1\frac{3}{4}$	$>4\frac{1}{4}$
10	-48	.0170	.0147	250	.0385	657	17.44	$2\frac{3}{4}$, 3	>5	-------	------
11A	-63	.0094	.025	236	.0525	493	18.56	-------	------	[b,c]$\frac{3}{4}$ [b]$2\frac{1}{2}$	$2\frac{1}{2}$, $3\frac{3}{4}$
11B	-63	.0094	.025	236	.0435	408	18.56	-------	------	[b,c]$\frac{3}{4}$ [b]$2\frac{1}{2}$	$3\frac{1}{4}$, $3\frac{1}{2}$
[f]12A	-7	.0146	.0135	197	.0241	352	15.3	-------	------	-------	------
[f]12B	-7	.0146	.0135	197	.0254	371	15.3	-------	------	-------	------

[b]Two types of spin.
[c]Recovery attempted before final steep attitude was attained.
[f]Recovery data not available for normal control configuration for spinning or criterion spin; analysis to determine fillet effect made on basis of other unpresented data.

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TABLE I.- MASS AND DIMENSIONAL PARAMETERS FOR MODELS USED IN FILLET INVESTIGATION AND RESPECTIVE RECOVERY CHARACTERISTICS BEFORE AND AFTER FILLET INSTALLATION - Concluded

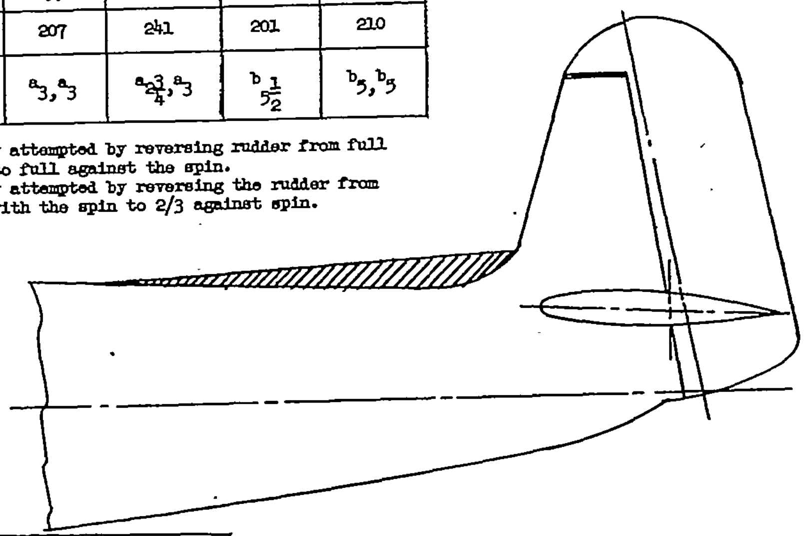
Model	$\frac{I_X - I_Y}{mb^2}$	URVC	TDR (without fillet)	TDPF (without fillet)	TDR (fillet installed)	TDPF (fillet installed)	μ (at test altitude)	Turns for recovery required for normal control configuration		Turns for recovery required for criterion spin	
								Without fillet	With fillet	Without fillet	With fillet
13	-56×10^{-4}	0.0062	0.02079	129×10^{-6}	0.0317	196×10^{-6}	14.8	∞	$3\frac{1}{2}$, $4\frac{1}{2}$, 6	∞	∞
14A	-62	.00678	.02064	140	.0274	176	10.43	-------	(f)	-------	(f)
14B	-62	.00678	.02064	140	.0326	222	10.43	∞	$3\frac{1}{2}$, $4\frac{3}{4}$	-------	------
15	-27	.00966	.0162	156	.0344	336	18.35	$^{b}3$ $^{b}2\frac{1}{2}$	$^{d}2\frac{1}{2}$	-------	------
16	8	.0645	.01338	120	.0348	225	16.55	-------	(f)	-------	(f)
17A	-18	.00975	.0206	202	.0371	362	24.9	$^{b}5\frac{1}{2}$, $^{b}8$ Steep spin	$2\frac{1}{2}$, $2\frac{1}{2}$	∞	$3\frac{1}{4}$, $3\frac{1}{2}$
17B	-18	.00975	.0206	202	.0478	466	24.9	$^{b}5\frac{1}{2}$, $^{b}8$ Steep spin	------	∞	4, $6\frac{1}{4}$
17C	-18	.00975	.0206	202	.0478	466	24.9	$^{b}5\frac{1}{2}$, $^{b}8$ Steep spin	------	∞	4
18	-36	.00772	.0295	177	.0495	356	16.91	Wandering and oscillatory spin	$2\frac{1}{4}$	-------	------
19A	6.3	.0265	.0398	1056	.0602	1595	15.67	$1\frac{3}{4}$, 2	$1\frac{1}{4}$, $1\frac{1}{4}$	2, $2\frac{1}{2}$	$1\frac{3}{4}$, 2
19B	6.3	.0265	.0398	1056	.0610	1618	15.67	$1\frac{3}{4}$, 2	1, $1\frac{1}{2}$	2, $2\frac{1}{2}$	2, $2\frac{1}{4}$
20	-38	.01359	.01723	234	.0315	428	12.25	-------	------	∞	$>4\frac{1}{2}$
21A	-40	.0126	.00571	72	.0125	157	7.5	>2, $>2\frac{1}{2}$	$2\frac{3}{4}$, 3	$2\frac{3}{4}$, $2\frac{3}{4}$	4, 5, 5
21B	-40	.0126	.00571	72	.0253	319	7.5	>2, $>2\frac{1}{2}$	$^{b}2\frac{1}{4}$, $^{b}4$, $^{b}4$ Very steep spin	$2\frac{3}{4}$, $2\frac{3}{4}$	∞, 6

[b]Two types of spin.
[d]Flatter of two types of spin obtained without fillets was eliminated with fillets installed.
[f]Recovery data not available for normal control configuration for spinning or criterion spin; analysis to determine fillet effect made on basis of other unpresented data.

TABLE II.- SKETCHES AND DATA FOR TWO TYPICAL MODELS WITH DORSAL FINS INSTALLED

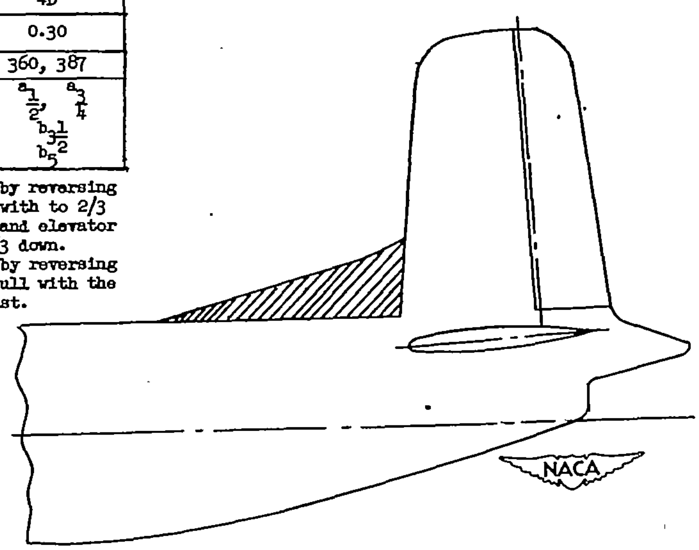
Aileron	Neutral		1/3 against	
Elevator	Full up		2/3 up	
Rudder	Full against		Full with	
Condition	Without dorsal	Dorsal installed	Without dorsal	Dorsal installed
α, deg	55	58	55	58
V, fps	207	241	201	210
Turns for recovery	[a]3, [a]3	[a]$2\frac{3}{4}$, [a]3	[b]$5\frac{1}{2}$	[b]5, [b]5

[a]Recovery attempted by reversing rudder from full with to full against the spin.
[b]Recovery attempted by reversing the rudder from full with the spin to 2/3 against spin.



Aileron	1/3 with	
Elevator	2/3 up	
Rudder	Full with	
Condition	Without dorsal	Dorsal installed
α, deg	22 18	23 44
ϕ, deg	1U 4D	7U 4D
Ω, rps	0.30	0.30
V, fps	344, 405	360, 387
Turns for recovery	[a]$\frac{3}{4}$, [a]1 [b]$2\frac{1}{2}$ [b]4	[a]$\frac{1}{2}$, [a]$\frac{3}{4}$ [b]$3\frac{1}{2}$ [b]5

[a]Recovery attempted by reversing rudder from full with to 2/3 against the spin and elevator from 2/3 up to 1/3 down.
[b]Recovery attempted by reversing the rudder from full with the spin to 2/3 against.



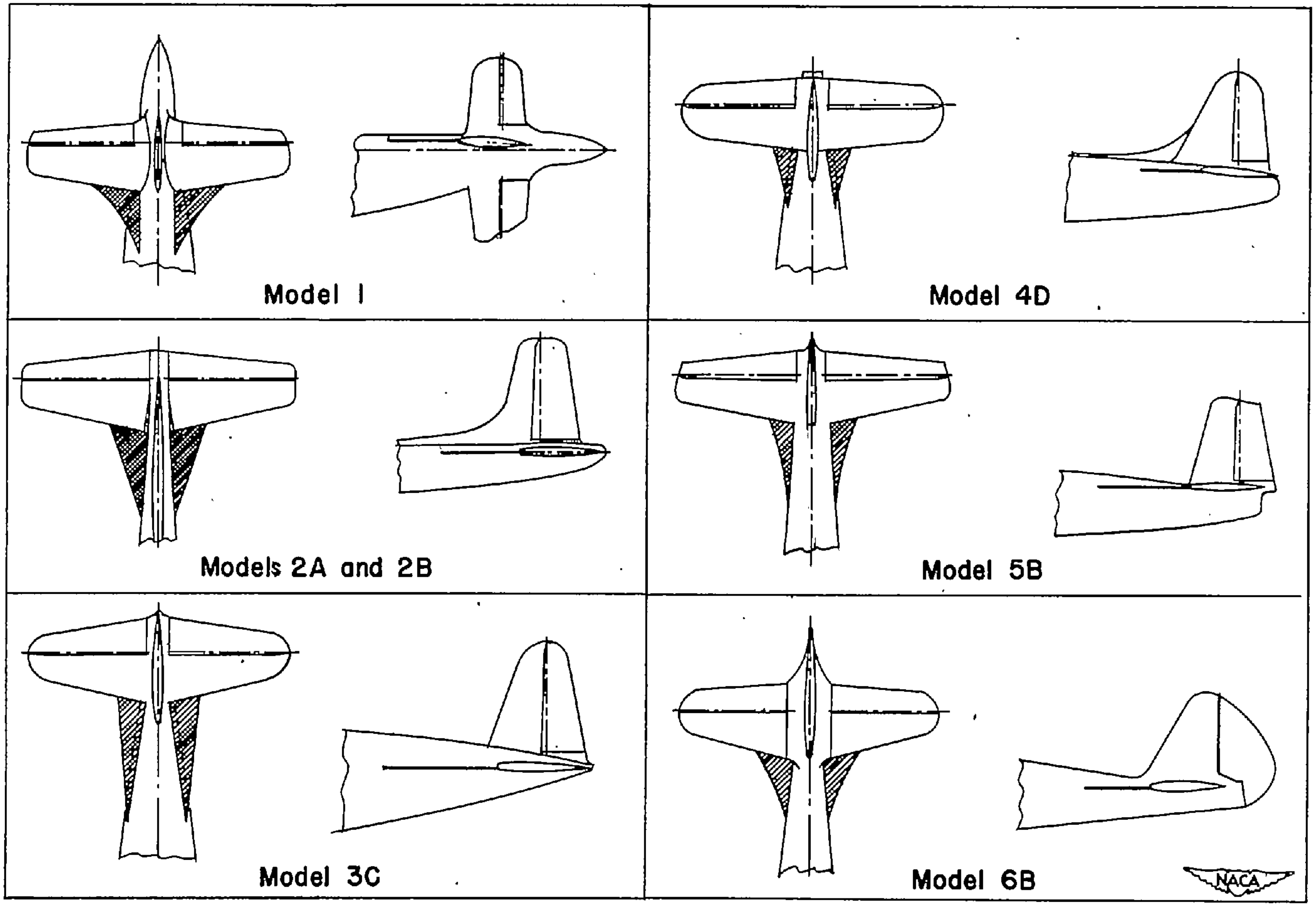


Figure 1.- Sketches of antispin fillets that had a satisfactory effect on the spin and recovery characteristics. (Model numbers refer to those given in table I.)

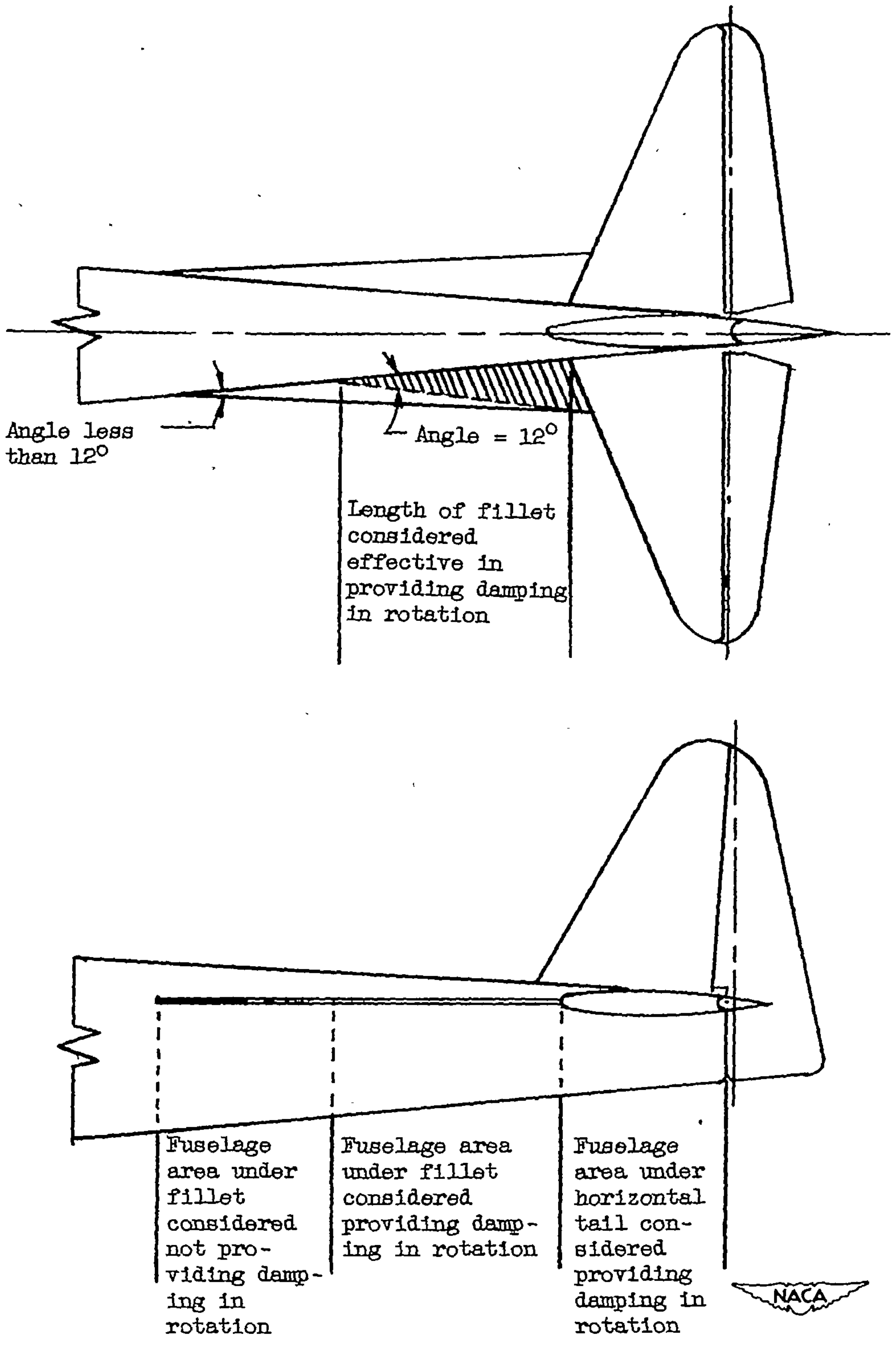


Figure 2.- Sketch of fillet for which not all the fuselage area below the fillet is considered effective in damping the spin rotation.

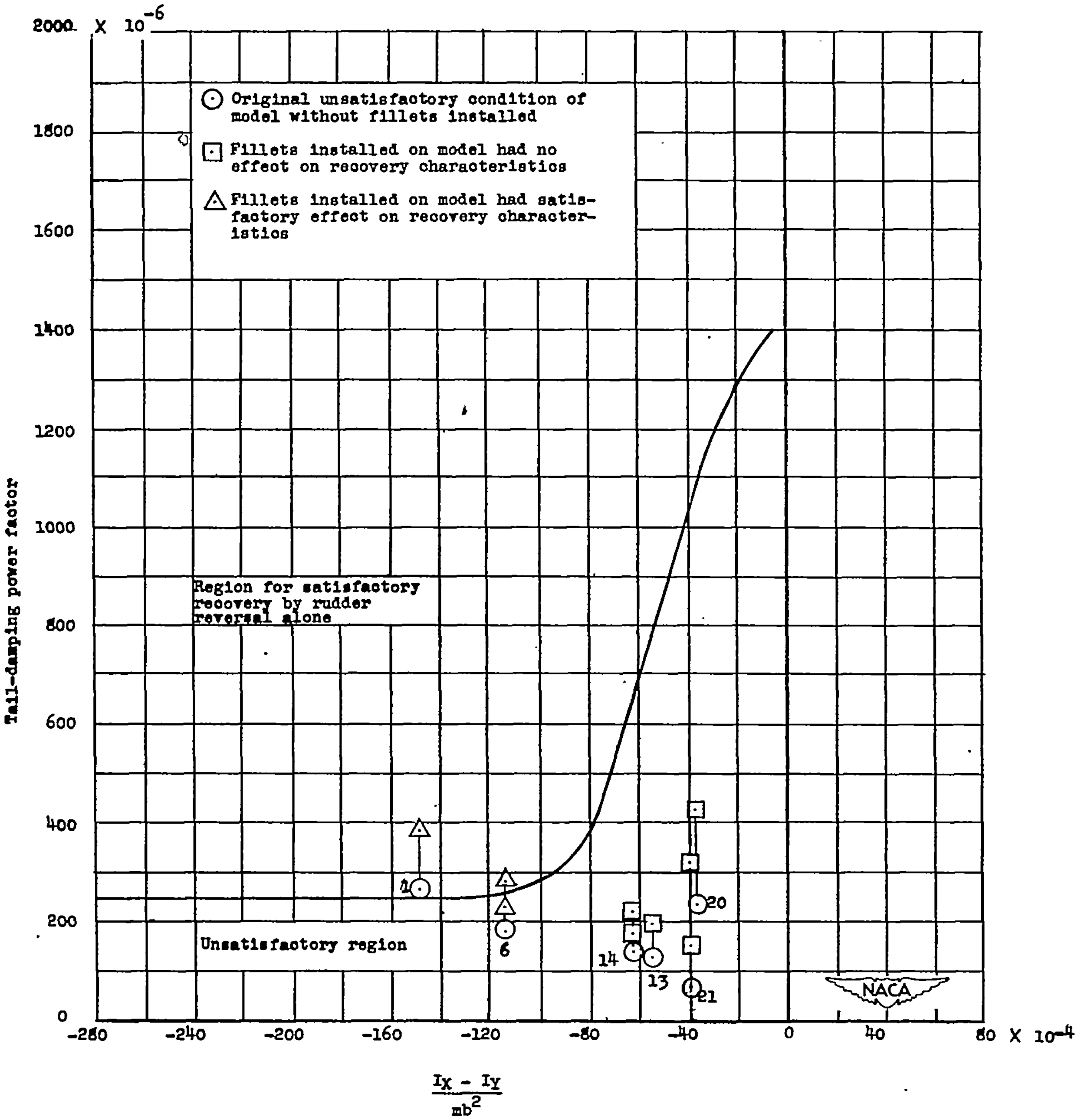


Figure 3.- Effect of antispin fillets on the recovery characteristics of airplanes with relative densities of 15 or less as related to requirements for tail design for satisfactory spin recovery. (Numbers placed near symbols refer to models listed in table I.)

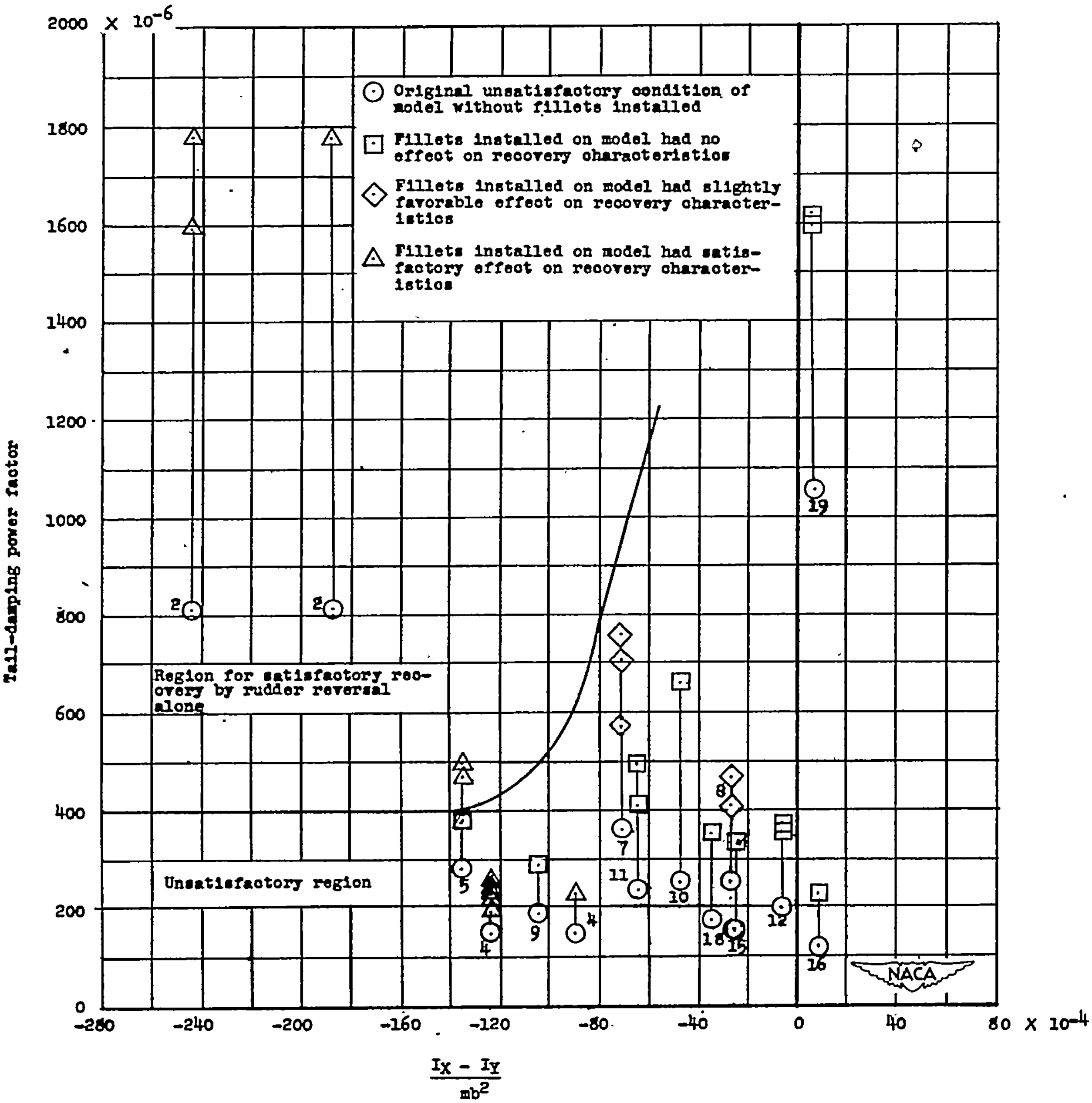


Figure 4.- Effect of antispin fillets on the recovery characteristics of airplanes with relative densities greater than 15 and as much as 20 as related to requirements for tail design for satisfactory spin recovery. (Numbers placed near symbols refer to models listed in table I.)

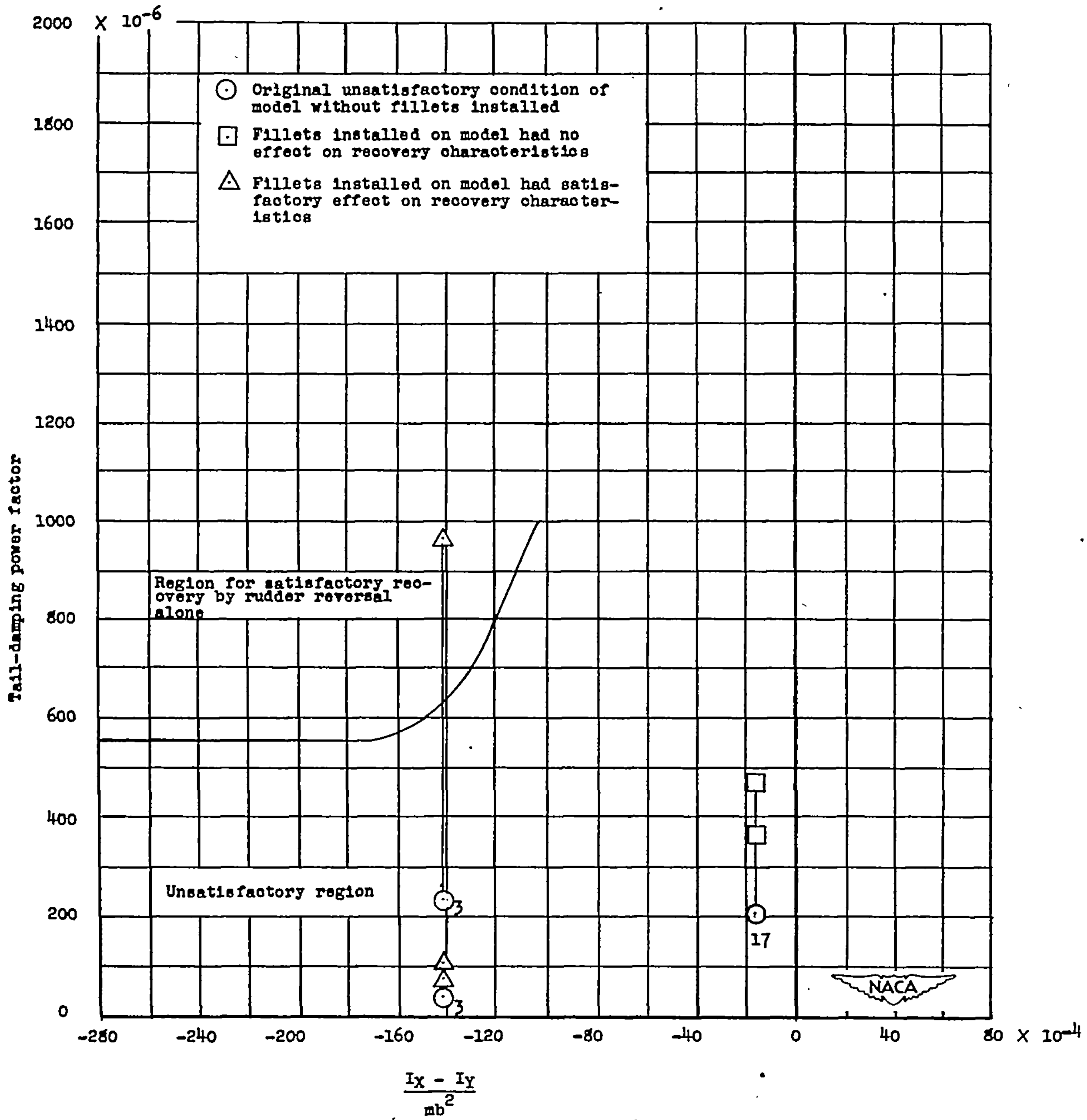


Figure 5.- Effect of antispin fillets on the recovery characteristics of airplanes with relative densities greater than 20 as related to requirements for tail design for satisfactory spin recovery. (Numbers placed near symbols refer to models listed in table I.)

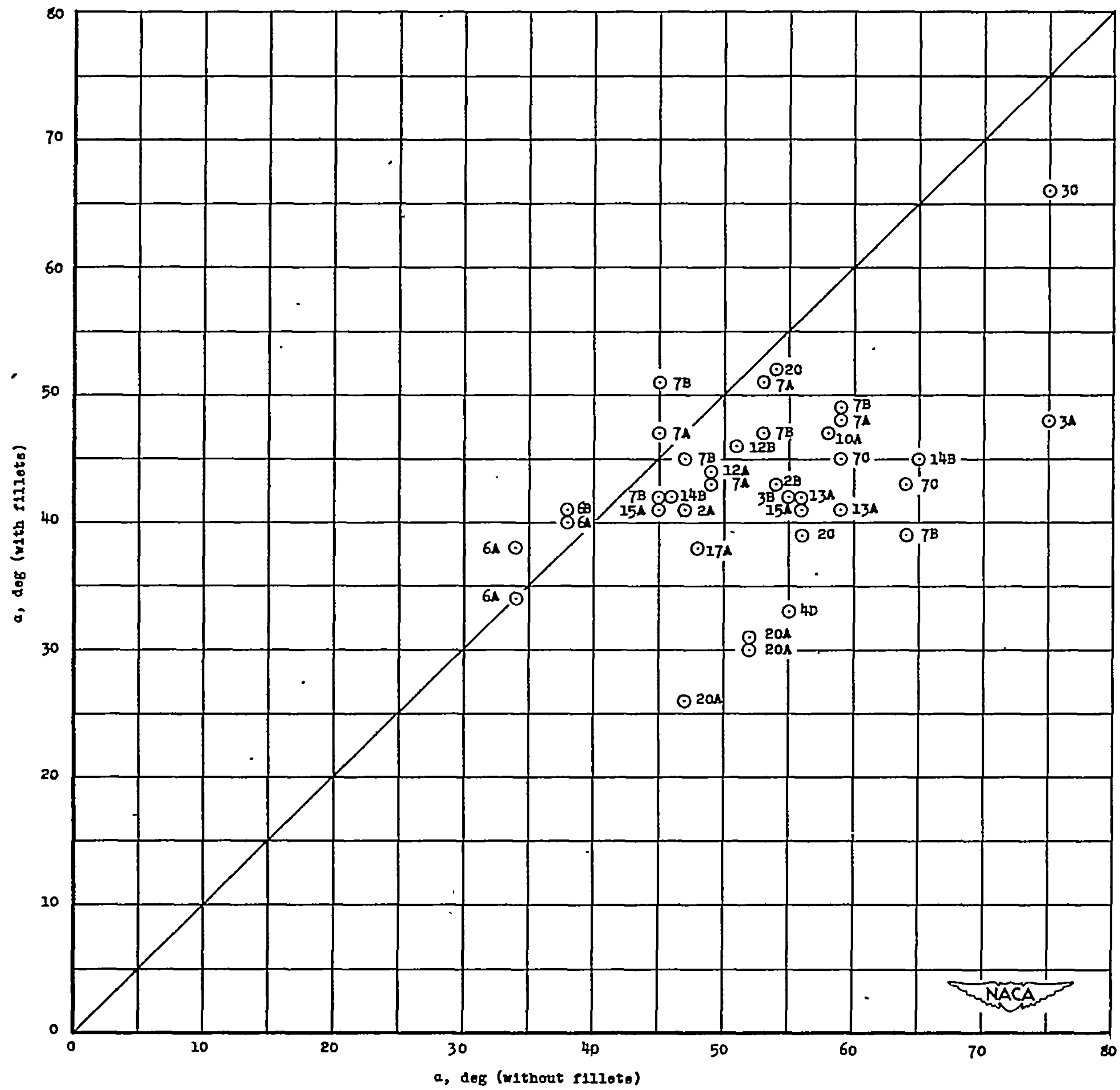


Figure 6.- Effect of antispin fillets on spin angle of attack. (Numbers placed near symbols refer to models listed in table I.)

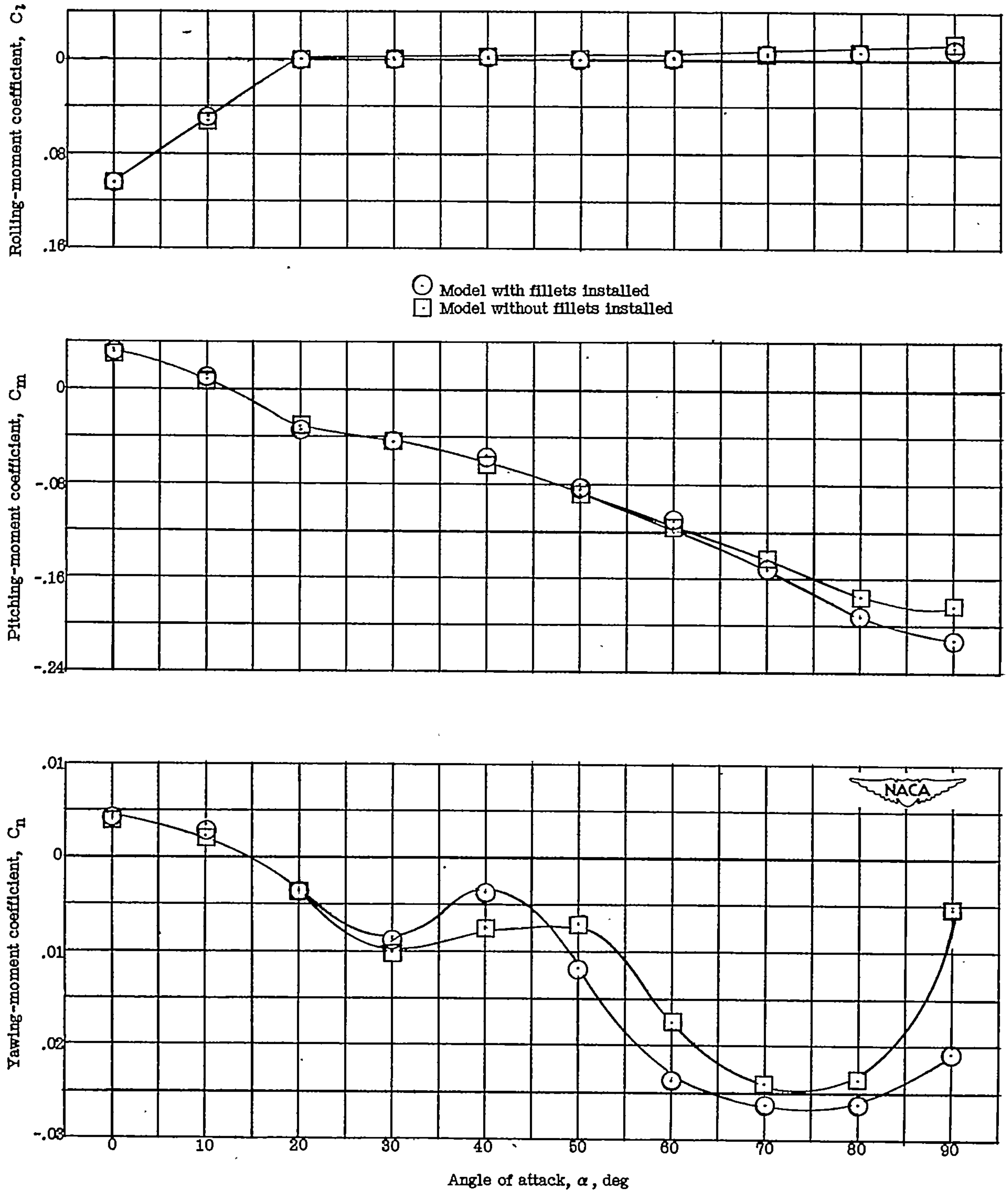


Figure 7.- Effect of antispin fillets on the rolling-, pitching-, and yawing-moment coefficients of a low-wing fighter-type airplane model (model 5A). The wing tilt angle and the spin radius were maintained at zero; $\frac{\Omega b}{2b} = 0.30$.